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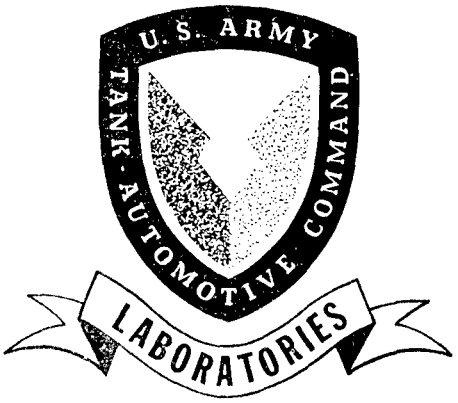
DEVELOPMENT OF URETHANE ROADWHEEL TIRES WITH EMPHASIS ON METHOD OF BONDING



JULY 1975

by John W. Cameron
Project Engineer
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TACOM
MOBILITY SYSTEMS LABORATORY
U.S. ARMY TANK AUTOMOTIVE COMMAND Warren, Michigan

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FINAL REPORT

DEVELOPMENT OF URETHANE ROADWHEEL TIRES WITH EMPHASIS ON METHOD OF BONDING (FIRST SIX SAMPLES)

U.S. ARMY TANK-AUTOMOTIVE COMMAND

ARMOR & COMPONENTS DIVISION

by

JOHN W. CAMERON

PROJECT ENGINEER

JULY 1975

SUMMARY

This project involved building six M113 road-wheels with urethane tires instead of the usual rubber tires. Urethane was expected to provide good resistance to wear and chunking but had a bad reputation for bonding. On these six wheels, various ways were tried to provide good bonding. On three of the wheels cord, impregnated with urethane, was wound around the rim to build up the tire. Screws were inserted into the rim to provide posts to guide the cord. Two of these three wheels failed in less than an hour on the drum test. Forty-eight hours without damage is considered successful for regular rubber tires. There were indications the impregnation of the cord with urethane was not thorough and not uniform. This, plus the screw posts and runout, caused severe bumping with a related build-up in tread temperature resulting in quick failure. The third cord wound tire appeared to be well and uniformly impregnated. In spite of bumping caused by screw posts and runout it ran very successfully and showed no degradation or damage after 97.9 hours. The temperature of the tread rose only moderately and the bumping was less severe probably because the durometer hardness was greater and more uniform due to better impregnation of the cord.

Two of the wheels used expanded metal (aluminum) welded to the rim of the aluminum wheel to provide a mechanical bond for the cast urethane. Both of these wheels passed the drum test successfully. One ran 96 hours at 10 mph with no damage. The other ran 48 hours at 10 mph and then six hours at 30 mph with no damage.

It was decided to make the sixth wheel with expanded metal but with a softer urethane so as not to decrease the ride quality. This wheel went 48 hours with no damage. Then it was put through the six hour - 30 mph test which it passed, but showed some signs of damage toward the end of the six hours. Subsequently it was subjected to another 48 hour test. During this test, some cracks resulted in the tread and the side but the tire was still strong enough so that the tread could not be stripped from the wheel. See table on Pg 8.

CONCLUSIONS

The tests indicate that the cord wound method might be successful but might be subject to quality control problems. Also in actual vehicle use where the track center guides sometimes dig into the tire and then tear out it is felt the cord might lead to more serious damage than present rubber tires experience. Therefore it is concluded that the best approach is to use the expanded metal bonding technique.

RECOMMENDATIONS

It is recommended that eight additional wheels with expanded metal bonding be procured for drum testing. The tires should be cast of polyether urethane with a Shore A durometer of 80^{+2}_{-5}. If these eight wheels are successful on the drum test, and if load deflection curves indicate that they will provide a ride quality similar to the present standard roadwheel, then it will be recommended that 30 wheels be procured for field testing on the vehicle.

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INTRODUCTION

This project is a test of M113 roadwheels made with urethane tires. Indications from past experience were that the urethane tires would provide excellent resistance to wear and chunking but that bonding would be a problem. In this test, various methods of overcoming the bonding problem were to be tried.

CONSTRUCTION

The remains of the old tires were removed and the aluminum wheels thoroughly cleaned. On two of these wheels expanded metal (aluminum) was heliarc welded to the rim. Then the wheel was sandblasted, primed, and 90 durometer hardness (shore A) urethane (polyether) was cast to form the tire. The urethane had a tensile strength of 6000 pounds per square inch and elongation of 400%.

On three other wheels screws were mounted in the rim as posts to guide while single strand polyesther cord, 100% impregnated with 90-A castable urethane, was wound on the primed wheel until the tire was fully formed with cast urethane filling out all surface areas.

Construction of a sixth wheel was held up until some test results were obtained from the earlier wheels. Then, based on that experience, it was decided to use expanded metal for bonding but to try a lower durometer urethane. It was felt the high durometer (90) urethane would cause the vehicle ride to be harsh (see Figure 1) and yet using a lower durometer might result in

much higher energy absorption resulting in higher tread temperatures and possibly short tire life. A urethane within the 70 $\pm$ 5 durometer hardness specified for the M113 rubber tires was requested. The supplier had to mix compounds from two different sources to try to meet this request. Note there were some flaws such as undercuts at joint between tire and wheel due to use of temporary forms. These were marked before testing started.

TESTS AND RESULTS

Wheel Number One - The construction was wound cord. The urethane was black and opaque. Durometer hardness was 66-73. The low hardness was probably due to the cord not being thoroughly impregnated with urethane. The wheel was put on the drum and run at 10 mph with a load of 2095 pounds. The standard M113 rubber tired roadwheel is considered to have successfully passed this test if it goes 48 hours without bond failure or blowout. This urethane tired wheel failed after 0.9 hour. Upon examination of the wheel, several areas of separation of tread and wheel were found. They were similar to blowout of standard rubber tires. This wheel ran with excessive vibration due to .045 inch radial runout and also probably caused by the screw posts used to guide the wound cord and also contributed to by variations in hardness of tire. Test was stopped due to extreme bumping. The wheel showed a blowout upon examination (see Figure 2). The ambient

temperature was 97°F. The wheel temperature was 125°F and the tread temperature was 160°F.

Wheel Number Two - The construction was yellow translucent urethane cast over expanded metal welded to the wheel rim. The durometer reading was 88-89. The wheel was put on the drum tester at 10 mph and 2095 pound load. It ran with some vibration and wheel tramp due to .015 inch radial runout. There was also excessive lateral runout. The wheel completed 48 hours with no degradation or damage. The ambient temperature was 97°F, and the highest tread temperature reached was 110°F. A decision was made to continue the drum test for another 48 hours. After the 96 hours no degradation or defects were observed. (See figures 3 and 4.)

Wheel Number Three - The construction was yellow translucent urethane cast over expanded metal welded to the wheel rim. The durometer reading was 91-92. The wheel was put on the drum tester at 10 mph and 2095 pound load. It ran with slight vibration. There was .010 inch radial runout. The wheel completed 48.75 hours without any degradation or defect. The highest temperature reached by the tread was 110°F. The ambient varied from 95°F to 100°F. This wheel was then subjected to a drum test at 30 mph with the load at 925 pounds for two hours, at 1015 pounds for two hours, and at 1110 pounds for the next two hours. The wheel showed no defects after this test. The ambient

temperature varied from 95°F to 102°F. The tread temperature reached 107°F. (See figures 3 and 4).

Wheel Number Four - The construction was wound cord. The urethane was orange and opaque. Durometer hardness was 81-88. The lower hardness and the large spread in durometer readings was probably due to the cord not being thoroughly impregnated or evenly impregnated with urethane. The wheel was put on the drum tester and run at 10 mph at 2095 pound load. Radial runout was .030 inch. Heavy vibration and bumping was present - sufficient to trip microswitch after twenty minutes. Machine was restarted. After another fourteen minutes the tire blew out. Tread temperature had reached 132°F. The ambient was 97°F. Wheel showed separation at cord wound reinforcement which extended from one side of the wheel to the opposite side and for 20° around the circumference. Another blowout was just starting about 120° from the first one. (See figure 5.)

Wheel Number Five - The construction was wound cord. The urethane was yellow and translucent. The durometer hardness was 90-91. Radial runout was .028 inch. The wheel was run on the drum tester at 10 mph and at 2095 pound load. There was moderate vibration. The test was continued for 97.9 hours. Maximum tread temperature was 117°F, and the ambient was 105°F. There was no noticeable degradation of the urethane compound or defect in the roadwheel at the conclusion of the test. (See figures 3 and 4.)

ANALYSIS OF FIRST FIVE WHEELS

Two cord wound wheels failed quickly and one succeeded admirably. The two that failed were softer and had a greater spread in durometer readings within the wheel. This was probably due to poor and inconsistent impregnation of the cord with urethane. This also probably led to more wheel vibration and bumping and a greater temperature build-up in the tread. While the one successful cord wound wheel would seem to indicate that a cord wound wheel can be successful there is some question as to the need for excessive personal attention to get consistently good quality - similar to present rubber tired roadwheels. Also all the cord wound tires had larger radial runout causing more vibration and more heat build-up. In addition in looking forward to vehicle use where track guides will occasionally misguide and dig into the tread it would seem that more of the tread might be ripped away with the cord winding than with the expanded metal construction. The two wheels with expanded metal bond both performed well. Therefore, it was decided that the expanded metal construction was more likely to be successful. It was decided to make the sixth wheel of expanded metal construction but with softer urethane, comparable to the 70 $\pm$ 5 durometer of the standard M113 rubber tire, so ride quality would not be sacrificed. (See Figure 1.)

Wheel Number Six - The construction was expanded metal. The

urethane was black, opaque and the durometer hardness was 76-79. This wheel, as on the previous samples, had undercut portions at the joint between wheel and tire and a putty material present at these places. The supplier explained that he used putty in the temporary molds he cobbled up. The wheel had .035 inch radial runout. The wheel was drum tested for 48 hours at 10 mph and with 2095 pound loading. The condition of the wheel was unchanged after this test. Then it was drum tested at 30 mph at 925 pounds for two hours, at 1015 pounds for two hours, and at 1110 pounds for two hours. Toward the end of the 30 mph test, the undercutting of the tread at the junction with the wheel became slightly more pronounced on both sides of the wheel. Now the wheel was subjected to an additional 48 hour drum test at 10 mph and 2095 pound load. After this test, increased undercutting with radiating cracks from undercut areas and circumferential cracks in tread surface were noted. The ambient temperatures were 90^{o}F to 101^{o}F. The tread reached a temperature of 122^{o}F after the first seven hours of running but then dropped back again to 112^{o}F. After the tests, the durometer hardness had increased to 77-81. There was only a slight vibration in spite of the .035 inch runout. An attempt was made to strip the tread from the wheel after the tests but it could not be done. Pieces of the tread were removed by sawing and the circumferential cracks were found to go about 2/3 to 3/4 the depth of the tread above the expanded metal. There was no

separation of the urethane from the expanded metal or the wheel rim. (See Figures 6, 7, and 8.)

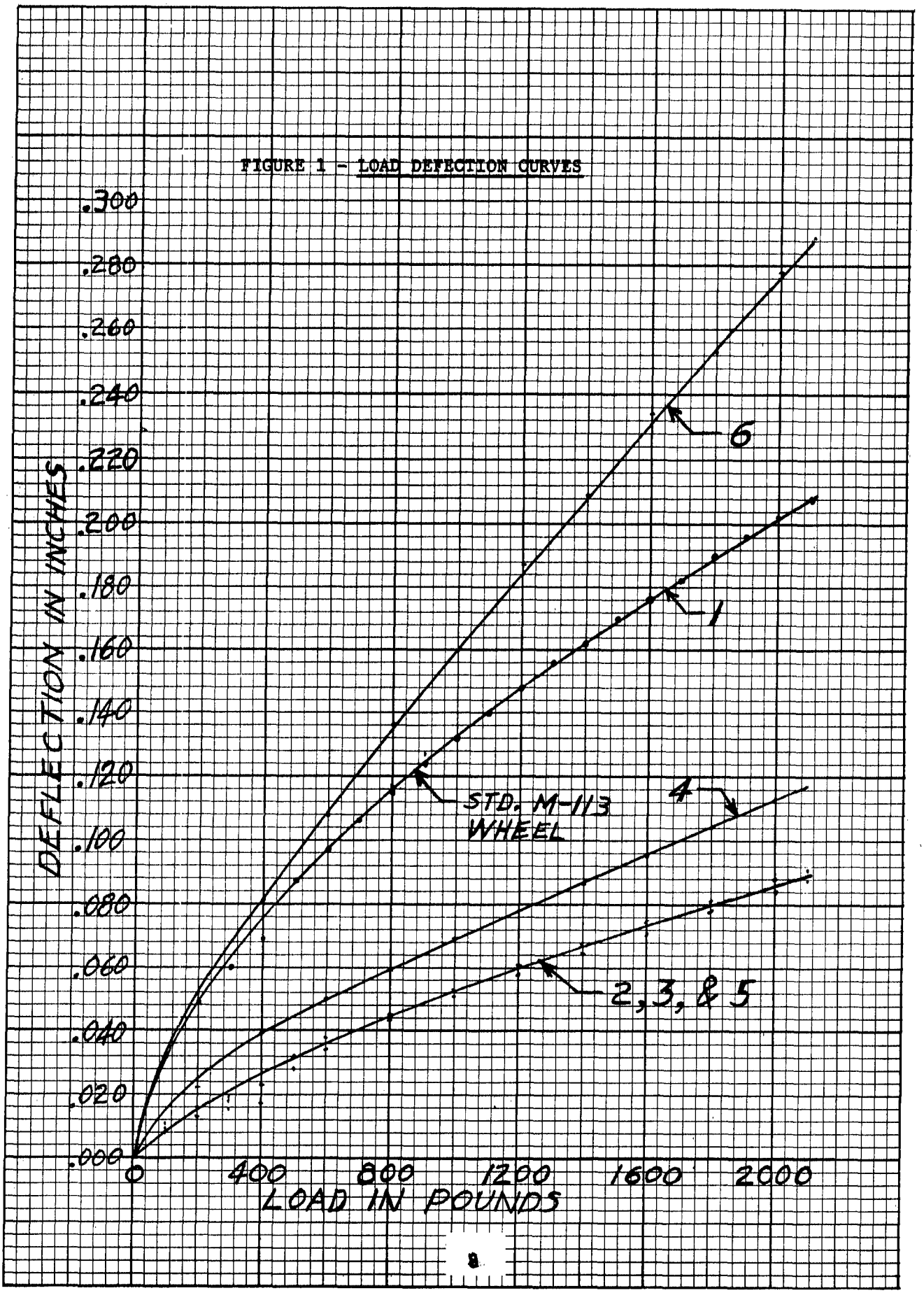


FIGURE 1 - LOAD DEFECTION CURVES

WHEEL #	COLOR	CONSTRUCTION	DUROMETER	WEIGHT in lbs	10 mph @ 2095 lbs	30 mph 2 hrs @ 925 lbs 2 hrs @ 1015 lbs 2 hrs @ 1110 lbs	10 mph 2095 lbs	FINAL CONDITION OF TIRE
1	Black Opaque	Cord	66-73	33.4	0.9 hrs			Failed (see photo) Excessive vibration. Tread Temp: 160° F.
2	Yellow Trans-lucent	Expanded Metal	88-89	33.1	48 hrs		48 hrs	Excellent. Tread Temp: 110° F. Vibration
3	Yellow Trans-lucent	Expanded Metal	91-92	32.7	48.75 hrs	6.0 hrs		Excellent. Tread Temp: 110° F. Slight vibration.
4	Orange Opaque	Cord	81-88	32.5	0.6 hrs			Failed (see photo) Excessive vibration. Tread Temp: 137° F.
5	Yellow Trans-lucent	Cord	90-91	32.9	48 hrs		49.9 hrs	Excellent. Heavy vibration. Tread Temperature: 117° F.
6	Black Opaque	Expanded Metal	76-79 (77-81: after test)	33.2	48 hrs	6.0 hrs	48 hrs	Excellent after 1st 48 hrs. Good after 6 hrs. Serviceable after 2nd 48 hrs. Tread temp: 122° F.

TABLE SUMMARIZING DRUM TESTS

FIGURE 2 - WHEEL NUMBER 1 AFTER TEST

FIGURE 3 - WHEELS NUMBER 2, 3, AND 5 (LEFT TO RIGHT) AFTER TESTING

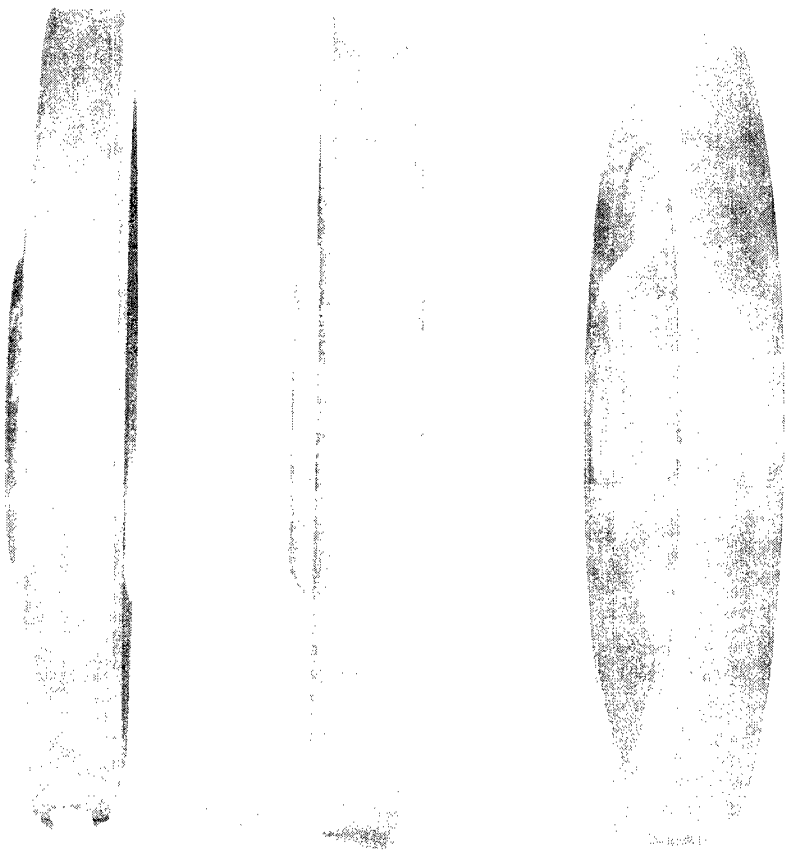


FIGURE 4 - WHEELS NUMBER 2, 3, AND 5 (LEFT TO RIGHT) AFTER TESTING

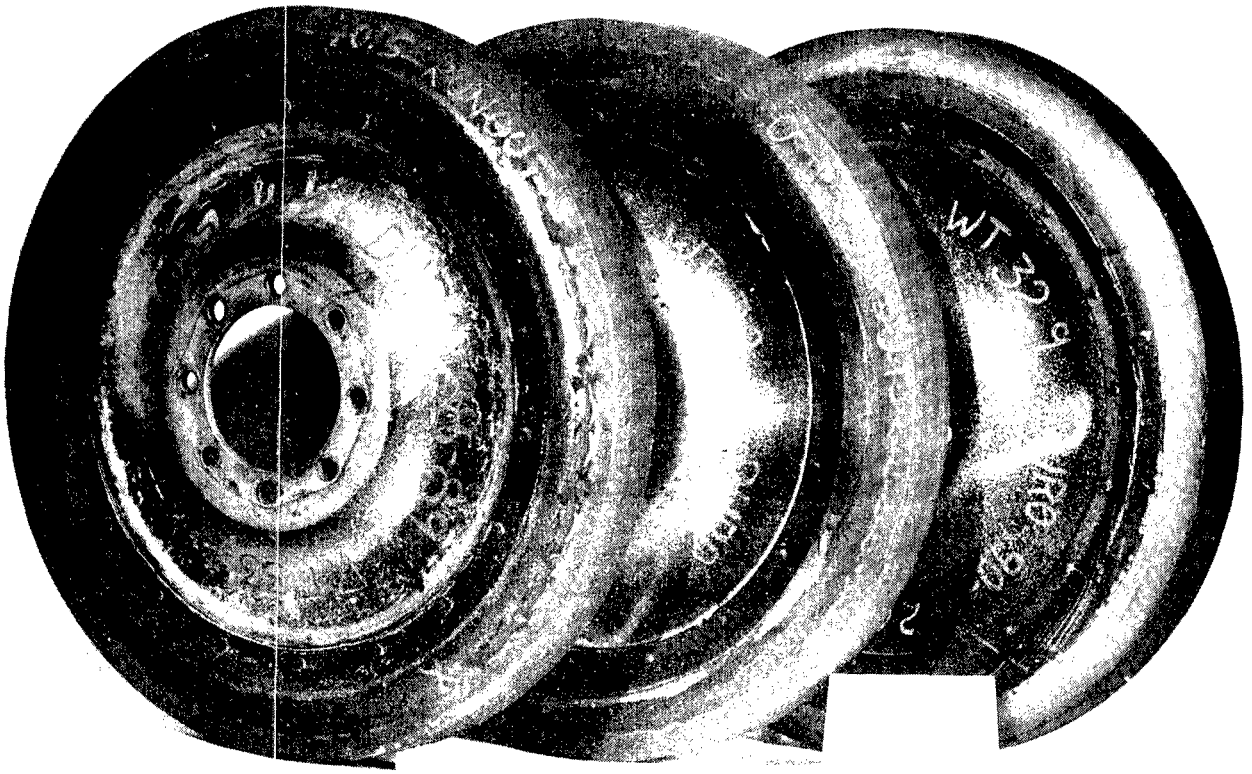


FIGURE 5 - WHEEL NUMBER 4. NOTE PRIMARY FAILURE AT 9 O'CLOCK AND SECONDARY AT 2 O'CLOCK

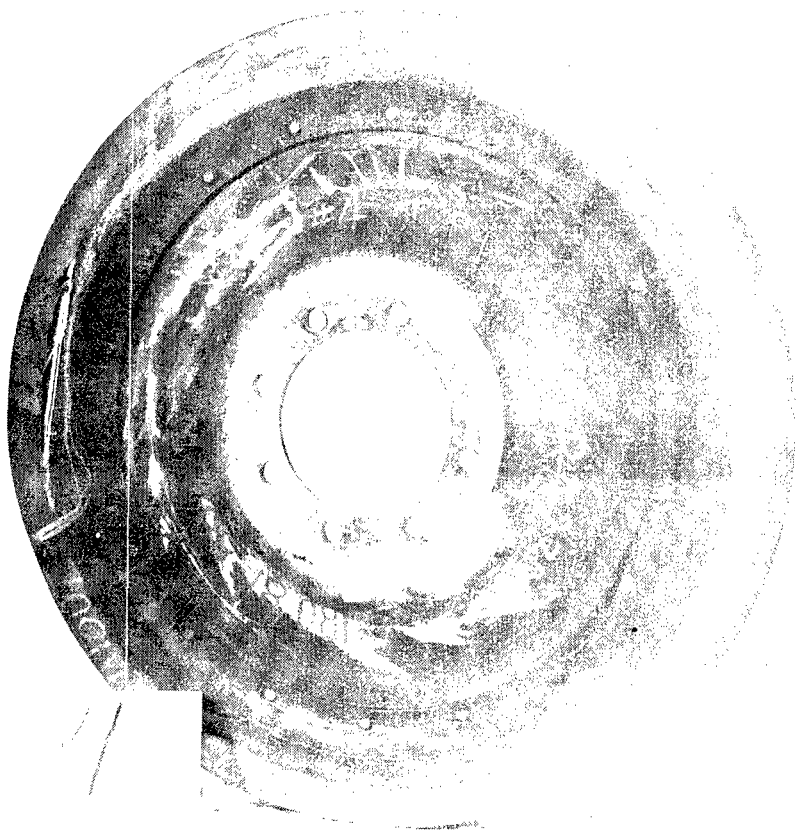


FIGURE 6 - WHEEL NUMBER 6 AFTER ALL TESTING.
NOTE UNDERCUT AREAS OF TREAD
CIRCLED WITH CHALK

FIGURE 7 - WHEEL NUMBER 6 AFTER TESTS.
CLOSEUP VIEW OF UNDERCUTTING

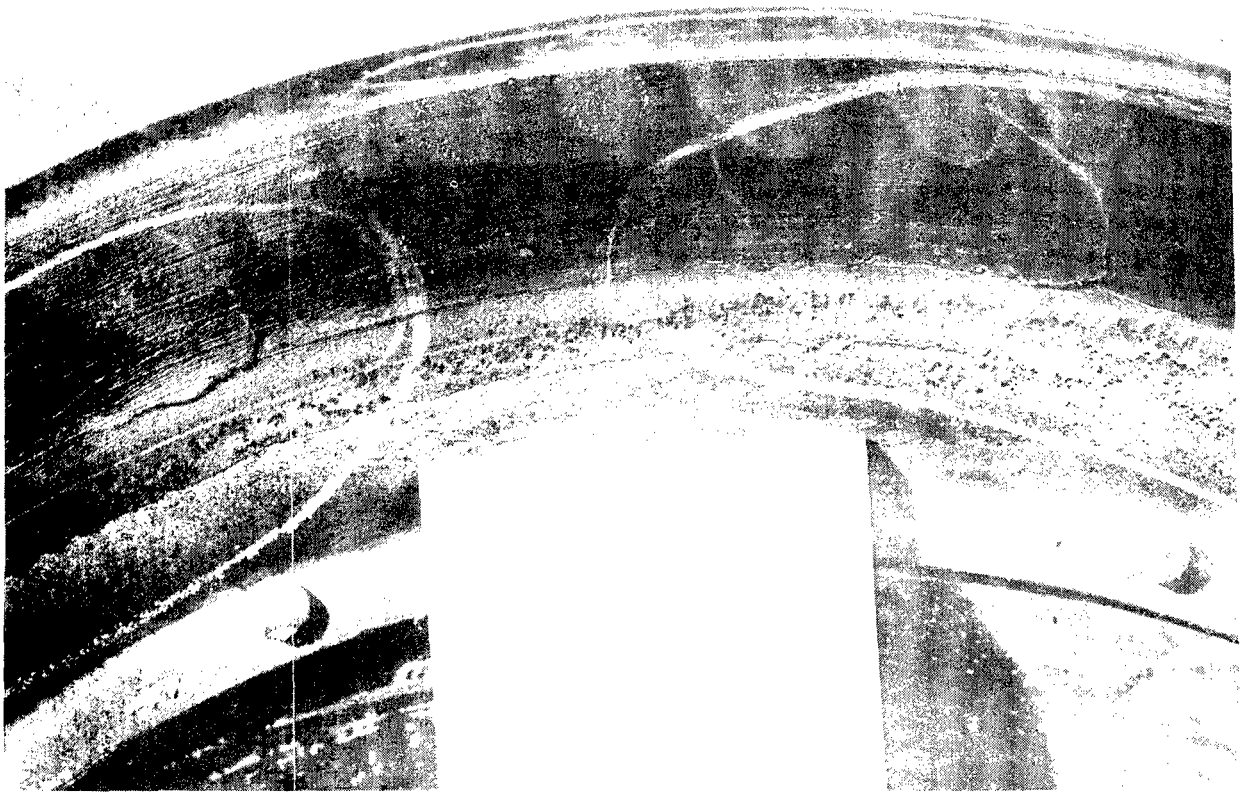
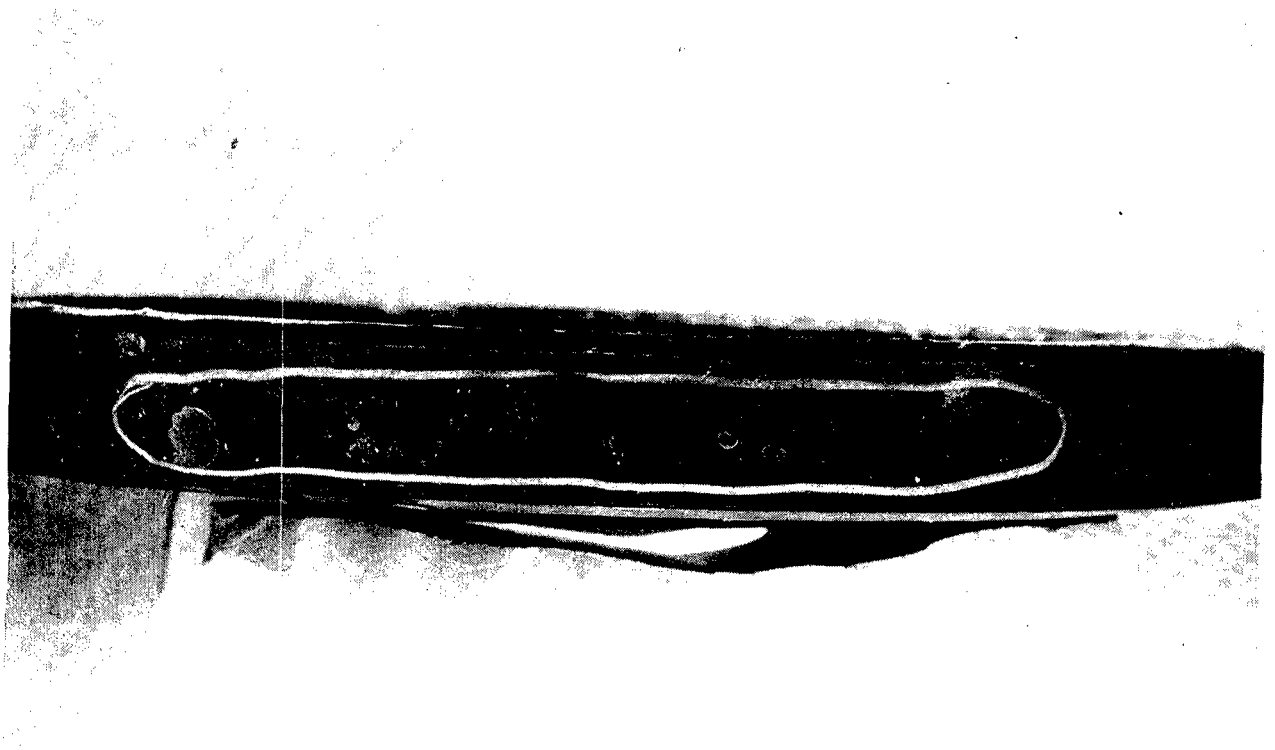


FIGURE 8 - WHEEL NUMBER 6 AFTER TESTS. NOTE CRACKS IN TREAD ONLY APPEAR WHERE THERE ARE FOREIGN INCLUSIONS IN THE URETHANE



APPENDIX I

TEST INSTRUCTIONS

1. The six M113 roadwheels covered by these instructions are experimental. The tires are urethane rubber and various bonding methods have been used. Please observe carefully, especially during early part of drum test, and report anything noticed.

2. Take durometer readings on each tire.

3. Prepare load deflection curve for each tire.

4. Mount the wheel on hub and spindle and check for radial runout. Record the total indicator reading.

5. The wheel shall then be loaded radially against the drum and run for 48 hours at 10 mph and at load of 2095 pounds. Observe during early part of test.

6. If tire is still in good condition after 48 hour test, instructions will be issued on a case by case basis to proceed with a six hour 30 mph test with load of 925 pounds for first two hours, then 1015 pounds for next two hours, and 1110 pounds for last two hours; or to proceed with another 48 hour test; or both of these.

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This program evaluates various methods of bonding solid urethane tires to roadwheels for tracked vehicles. Mechanical bonding through expanded metal welded to wheel rim looks promising and will be further evaluated through additional drum tests with urethane of different durometer hardness to refine specs to be used for procuring wheels for field test on vehicle.

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